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IDA MEMORANDUM REPORT M-552

SOFTWARE TECHNOLOGY DEVELOPMENT AND DEPLOYMENT PLAN FOR THE DoD TECHNOLOGY BASE

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April 1989

Prepared for
Deputy Director Defense Research and Engineering
Research and Advanced Technology (DDDR&E(R&AT))

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The purpose of IDA Memorandum Report M-552, *Software Technology Development and Deployment Plan for the DOD Technology Base*, is to document the findings of three workshops sponsored by the Institute for Defense Analyses (IDA). The participants were asked to place primary focus on actions that could enhance DOD's ability to deploy software intensive weapon systems, to capitalize on the findings, conclusions, and recommendations of previous DOD software studies, and to draw from their own personal experiences. The IDA study took a different approach than the previous studies by addressing those common user problems directly related to the deployment of operational software intensive weapon systems. The results were five key findings and recommendations for the DDDRE(R&AT) that address specific technology base efforts as well as DOD policy/management infrastructure (continued)

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SOFTWARE TECHNOLOGY DEVELOPMENT AND DEPLOYMENT PLAN FOR THE DoD TECHNOLOGY BASE

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PREFACE

The purpose of IDA Memorandum Report M-552, "Software Technology Development and Deployment Plan for the DoD Technology Base," is to document the findings and results of a workshop study. The workshop participants were asked to place primary focus on software technology base actions and recommendations that might enhance the Department of Defense's ability to deploy software intensive weapon systems.

This document is intended to fulfill the objective of Task Order T-D5-627, A Software Technology Development and Deployment Plan for the DoD Technology Base, and to serve as an additional input for the next Deputy Director of Defense Research and Engineering (Research and Advanced Technology) (DDDRE (R&AT)) Program Objective Memorandum (POM)/budget review in mid-FY1989. The report focuses on some of the potential actions that the DDDRE(R&AT) may consider to improve the development and deployment of software technology in systems.

An earlier draft of this report was provided to all of the workshop participants for review and comment. The final draft of the report was reviewed within the Computer and Software Engineering Division (CSED) by T. Mayfield, S. Nash, and C. Linn.

EXECUTIVE SUMMARY

This study was requested by the Deputy Director of Defense Research and Engineering (Research and Advanced Technology) (DDDRE (R&AT)), to develop a Software Technology Development and Deployment Plan for the DoD Technology Base. A series of three workshop meetings, chaired by Dr. Ruth Davis, was held in November 1988, December 1988 and early January 1989. The workshop participants were asked to place primary focus on actions that could enhance the Department of Defense's ability to deploy software intensive weapon systems, to capitalize on the findings, conclusions, and recommendations of previous DoD software studies, and to draw from their own personal experiences.

This study attempted to take a different approach than previous software studies by addressing those common "user" problems directly related to deployment of operational software intensive weapon systems. The recommendations are based on the findings and perceptions resulting from the three workshops. The workshop participants reiterated that DoD has a number of operational systems with critical software-related problems and that the software-related cost of maintenance and support for DoD systems is rising dramatically. Although DoD has asked various experts to address these growing software-related problems on several occasions, to date, the majority of their recommendations have not been implemented. The participants felt that a lack of a central DoD focus on software-related issues has contributed to the relatively slow resolution of software problems across DoD. Finally, they felt that applying research and development to software-related technology problems currently experienced on deployed systems would not only permit early realization of software technology enhancements, but through the resulting demonstrated benefits, would also stimulate more advanced software technology applications across systems and Services.

The workshop resulted in five key findings and recommendations for the DDDRE (R&AT) that address specific technology base efforts as well as DoD policy/management infrastructure changes that should be considered for immediate action.

a. Deployed Military Software Improvement Programs: Establish a comprehensive approach for improving military software during deployment. The focus should be on the phases of the software life cycle that have the most influence over the deployment of software intensive systems. The approach should include a series of demonstration projects that focus on developing system upgrades for operational software intensive weapon systems currently experiencing critical software difficulties.

b. Software Technology Funding Support: The Service Laboratories' software technology base programs and the DoD Software Initiative (Ada, STARS (Software Technology for Adaptable, Reliable Systems), and SEI (Software Engineering Institute)) should continue to be supported and fully funded for FY 1990. Since the rate of software technology evolution has not kept pace with DoD weapon systems' growing requirements for more software with increasing complexity, DoD should reassess the software technology base requirements for FY 1991 to ensure that the software technology base funding priority is increasing commensurate with the trend of increasing software-related deployment costs.

c. Generic Software Technology High Priority Efforts: The Services and Agencies should be tasked to establish "lead agents" for selected critical software technology areas. The lead agents should be carefully selected from within the Services for their expertise in software-related disciplines. The primary functions of the software lead agents would be to identify Service software technology related problems and requirements, to share software technology information with DoD and the Services, and to stimulate advanced software

technology application across Services and program offices.

d. Recommendations of Previous Studies: The Science and Technology Committee of the Defense Acquisition Board should be tasked to review the recommendations of the September 1987, Defense Science Board Task Force on Military Software and to sponsor and promote their implementation.

e. DoD Software Responsibility and Authority: Establish an immediate initiative to consolidate DoD software and computer policy, management, and oversight within a structured forum (with both responsibility and authority) that is commensurate with software technology's growing importance. The following were recommendations developed during the workshop to specifically address this very complex software-related responsibility and authority problem.

   1. Establish a Director of Military Software Improvement, within the Office of the Under Secretary of Defense (Acquisition), responsible for identifying, managing, integrating and implementing software deployment policy.

   2. Establish a committee under the co-chairmanship of the Director Defense Research and Engineering and the Assistant Secretary of Defense (Production and Logistics) with representation from the Assistant Secretaries of the Services. The committee will provide a direct forum for addressing policy and program issues that transcend Service and Agency requirements.

   3. Develop and distribute a software responsibility and authority guide. The intent of the guide should be to clearly outline the various software-related roles and responsibilities within OSD and permit a greater understanding of the current software policy, review, coordination and oversight related processes within DoD.

1. PURPOSE

This report documents an Institute for Defense Analyses (IDA) study conducted under Task Order T-D5-627 for the Deputy Director of Defense Research and Engineering (Research and Advanced Technology). The objective of the study was to generate one or more options for a software technology development and deployment plan for the DoD Technology Base. Subordinate goals of the study were to capitalize on the results of previous software studies while focusing on operationally manifested software technology problems, and to serve as an additional input for the next DDDRE(R&AT) Program Objective Memorandum (POM)/budget review in mid-FY 1989.

1.1 Scope

The study was performed via a series of three workshop meetings conducted by IDA and chaired by Dr. Ruth Davis. The workshop participants were selected for their in-depth technical background and personal expertise over a wide range of software-related technologies including software intensive weapon system applications. Appendix A includes a list of the workshop participants.

The first workshop focused on military requirements for computer and software technologies, with special emphasis on system operational deployment and long-term support requirements. The second workshop addressed opportunities for improving software-related technology deployment. This workshop focused on current DoD software-related programs and on the findings of recent studies citing DoD software-related problems. The third workshop focused on software intensive weapon systems deployment and support problems as viewed from a user's perspective. Because there appeared to be a number of studies (along with measurable amounts of work) addressing software technology base issues relative to future systems, the workshop participants narrowed the study to focus on software technology problems that directly relate to current deployment of operational weapon systems.

In the context of this report, *software technologies* were defined to include software products (tools and packages) as well as related development and support technologies (programming, documentation, environments, testing, etc.). *Software deployment* was defined as the development, use, management, modification and support of software systems. Therefore, software deployment as used in this report includes system software development, operational prototyping and/or test-bed development, operational test and evaluation, operation and maintenance, and upgrading and/or updating.

From this perspective, the workshop participants were asked to identify actions that would enhance DoD's ability to deploy software intensive weapon systems. Additionally, the participants were chartered to capitalize on previous software studies. Recommended actions were to be based on current military requirements, ongoing and planned development, advanced technology software efforts, and current policy and management philosophies. In particular, the "military software" operational objective adopted was the "deployment" of software in weapon and support systems that measurably meets or exceeds operational requirements, delivery schedules, product quality specifications, maintenance service demands (including development necessary for upgrading), and cost targets.

2. BACKGROUND

2.1 Interdependencies of Software Technology and Military Capabilities

Software is an essential element of technologically superior weapon systems and provides a major contribution to DoD military capabilities found in ground, sea, air, and space systems. "The size and complexity of this software has been growing exponentially, because designers choose to implement needs of the increased functional complexity of these systems in software" [Zraket et al. 88, 1]. In addition, the Defense Science Board further substantiates this observation. "The 'smarts' of smart weapons are provided by software. Software is crucial to intelligence, communications, command, and control. Software enables computerized systems for logistics, personnel, and finance. The 'chief military software problem' is that we cannot get enough of it, soon enough, reliable enough, and cheap enough to meet the demands of weapon systems designers and users. Software provides a major component of U.S. war-fighting capability" [DSB Sept. 87, 6]. As a consequence, more and more of DoD's weapon systems are directly dependent on advancing software technologies. Once software intensive systems are deployed, DoD must possess the critical capabilities to maintain and evolve the software in these weapon systems throughout the life cycle.

2.2 Highlights of the Life Cycle

The life cycle of software is inextricably tied to the life cycle of the weapon system. Early weapon system development decisions directly influence the software life cycle through necessary trade-offs at the system engineering and program manager levels. Typical design trade-offs that influence the software life cycle include operational user requirements vs. maintenance needs; hardware/software partitioning; and the dominant cost, schedule and performance constraints.

Software is very often the ultimate pacing technology in weapon system development programs. This software life cycle begins with a system concept and initial program formulation. Detailed software development generally occurs late in the weapon system development cycle, and is generally paced by the design and development processes for the hardware and architectural configurations. Evolving weapon system needs and late selection of hardware configurations also exacerbate these long software development cycles. It is not uncommon for the software design process to extend well after the operational testing with new software being implemented as "block changes".

Software is perceived by DoD as offering significant opportunities to meet changing requirements as deployed software-intensive systems evolve. For example, after initial system deployment and throughout the remaining life cycle, it is generally easier and less costly to modify the software of digital computers than it is to modify analog hardware either to correct identified problems or to introduce evolving requirements. The Air Force's experience on the F-111 program exemplifies this condition:

> The Air Force upgraded the avionics of its F-111 A/E aircraft by altering their analog (hard-wired) computers. It also upgraded the avionics of its F-111 D/F aircraft, introducing the same new capabilities by altering the software in their digital computers. The hardware changes cost fifty times as much as the software changes and took three times as long to make. [Canan, 86, 50]

2.3 Significant Trends

DoD weapon systems are becoming more software intensive. Software and computer technologies are providing the essential link enabling system designers to integrate various functions into system designs rather than having to implement each function as a discrete subsystem. These new technologies also provide designers with unique opportunities to distribute and even share functional elements within systems, thereby reducing overall size,

weight, and power requirements while often increasing mission capabilities. The tremendous growth trend in software requirements is illustrated by the following observation:

> Growth in the numbers, speed and power of the embedded hardware has increased the length and complexity of the software used to run the computers. The F-16D has 236,000 lines of code, versus 135,000 on its predecessor, and the 500,000 lines of code on the B-1A bomber introduced in 1976 grew to 1,387,000 statements on the B-1B ten years later. It is estimated that the ATF [Advanced Tactical Fighter] will require as many as seven million lines of code (and the software for trainers and ground support will add another three to five million lines). [Tenenbaum 1987, 3]

The extent of systems software requirements growth is further exemplified by the April 7, 1988 DoD Inspector General's report on the Defense-wide Audit of Support for Tactical Software.

> The cost of acquiring and maintaining software is expected to grow dramatically over the next several years. An Electronics Industries Association Study developed for Congress in 1980, and updated in 1985, estimated that mission-critical computers in DoD will grow from approximately 10,000 in 1980 to about 350,000 in 1987. Similarly, the cost of the computers for military applications was projected to increase from about $1 billion annually in 1980 to about $6 billion annually in 1990 through 1995. However, the software acquisition and maintenance cost for the computers was projected to increase from about $3 billion in 1980 to about $29 billion in 1990, and about $42 billion in 1995. [OIG 1988, 1]

Commercial Off-the-Shelf (COTS) software and computer systems will meet some of DOD's requirements, but not all of them. The commercial software sector's primary focus is different and generally inadequate to meet many of the DoD real time and adaptive weapon system requirements. The workshop participants were in unanimous agreement with the following observation of the Defense Science Board Task Force on Military Software: "Mission-critical military software is more universally real-time, communications-oriented, and resource-constrained than its civilian counter parts. At any given time, the demands of weapon systems stress the state of the software art more severely than do civilian demands." [DSB, Sept. 1987, 7]

The growth in system software requirements is due, in part, to the rapidly advancing digital microelectronics technology. These microelectronic advances have permitted more functionality to be implemented within the specified design constraints. This increase in systems functionality has given rise to an enormous growth in software production demand. In order to keep pace with this demand growth, DoD needs to address improvements in technologies which can favorably impact the software development, production and evolution process.

The DoD unique mission-critical military software deployment problems will be further exacerbated by shortages of computer and software specialists. The Government versus private sector pay differential coupled with the poor training programs for programmers often deters potential applicants. For example, an entry level programmer for DoD earns just a little over 15 thousand dollars, whereas an entry level programmer performing the same work in the private sector will earn over 7 thousand dollars more. This resource problem will continue as the demand for programmers increases.

For some time, there has been a significant shortage of computer system analysts and computer programmers within the United States. The Bureau of Labor Statistics predicts an increase in this shortage for the 1990s. In the *Projections 2000* bulletin, published in March,

1988, the demand for computer specialists is predicted to increase by 60 to 85 percent by the year 2000. This increase in demand could be even more pronounced for programmers with Ada backgrounds.

Shortages will also be exacerbated by changing demographics and college student career preferences. The last of the "baby boomers" have completed college, and enrollment is expected to decrease by more than 5 percent through the year 2000 according to the Bureau of the Census. In addition, between 1982 and 1986, college freshman career preference for computer science fell from 8.5 percent to 4 percent according to the Higher Education Research Institute. There is no question that there will be a critical shortage of computer specialists throughout the next decade. [DOL 1988]

2.4 DOD Software Technology Programs

This section of the report provides a synopsis of ongoing DoD software-related technology base (or technology-base like) programs. The information was included if the program was generic in nature and excluded if there was a specific (immediate) application target.

The combined Army, Navy, and Air Force software-related technology base efforts for FY88, FY89, and FY90 were budgeted at $64.9M, $75.2M, and $69.1M respectively. Since budget and programmatic data are always in a state of flux, this budgetary information is considered current only as of July 1988. The source data for these summaries were the briefing charts from the Services' Science and Technology review of the computer and software technology base programs given to DOD during the summer of 1988.

Three other high visibility DOD programs - Ada, the Software Engineering Institute (SEI) and the Software Technology for Adaptable, Reliable Systems (STARS) Program - are funded at approximately $25.0M, $18.8M, and $17.7M, respectively for FY89.

There are additional software-related development efforts under the specific sponsorship of Service program offices/Agencies; however, the effort necessary to assemble data on these other software-related programs is beyond the scope of this study. Therefore, the following summary of the planned FY89 of SDIO software technology base budget is provided as an example of other ongoing Service/Agency efforts.

a. Software Engineering Environments - $4.0M
b. Trusted Software - $5.2M
c. Distributed and Real-Time Operating Systems - $4.7M
d. Parallel Programming - $3.0M
e. *Other* - $1.9M

The workshop participants voiced unanimous concern that the software technology base funding was not keeping pace with the rapid increases in software-related acquisition and maintenance costs. Workshop discussions focused on the fact that participants of the Services' Science and Technology review observed that the software-related technology base funding may be over estimated by between 10 to 50 percent because of the close coupling to specific computer hardware development and acquisitions. Even at these possibly inflated funding levels, the combined FY 89 software technology base funding allocations will be less than 0.3 percent of the anticipated DoD software acquisition and maintenance burden of $29 Billion in 1990.

2.5 Overview of Recent Software Studies

Several recent software studies [DSB 1987; Zraket 1988; Nash 1988; Druffel 88; OIG 88] recognize that the DoD acquisition and management policies contribute to, and even induce,

many of the current software deployment and operational problems. In addition, these policies often impede attempts to resolve critical long term operational problems in current software intensive weapon systems. There was no single problem identified in these studies but rather they identified a series of problems that tend to be repeated over and over again. Table B-1, in Appendix B, summarizes the categories of the identified software issues addressed in these reports.

3. IDENTIFICATION OF HIGH PRIORITY SOFTWARE-INDUCED OPERATIONAL PROBLEMS

The following sections address DoD software-related problems from three different perspectives: *operational system problems*, the *systems acquisition process*, and *generic software technology areas*. These problems were identified by the workshop participants, and are based both on their own personal operational experiences as well as their many technical interchange meetings with weapon system operators and military commanders.

The workshop participants attempted to view these DoD software problems from a "user/commander" perspective. A summary of the military software deployment problem, from this perspective, follows:

a. There are growing allegations and perceptions that software, treated in its broadest sense, is the principal flaw degrading the performance and capabilities of many of our most essential military and intelligence systems.

b. The dependence on software in our most critical military and intelligence systems is increasing, not decreasing.

c. The dependence on software is increasingly viewed as a crippling operational problem because (1) operational readiness of delivered software is difficult, if not impossible, to certify; (2) software delivery seems to always be late; (3) documentation is marginal for field utilization; and errors are difficult to isolate.

d. Software activities needed to extend the life of weapons systems are often not funded with their companion equipment upgrades. Hence, software is frequently the "named culprit" in life extension failures.

Technology advances in many disciplines (sensors, microelectronics, computers, software, etc.) have permitted designers to incorporate higher levels of system complexity and functionality within assigned weight and volume constraints. These technology advances have permitted designers to cost-effectively implement, control and integrate various functional capabilities with software. It is important to recognize that up until around ten to fifteen years ago that such user-perceived problems would have focused on various hardware functions that are now implemented, controlled and integrated with software. What is critical in this observation is that currently (and for the foreseeable future) more and more system functionality is directly tied to software; and therefore, a higher percentage of the system design and evolution problems will move from the hardware to the software-related technology domain. This transitioning trend is evident in the three different perspectives of software-related problems discussed in the following sections.

3.1 Operational System Problems

This section of the report takes a different approach from the many studies referred to in Section 2.5, and addresses the types of common software problems directly related to deployment of operational weapon systems.

Many of the common problems may be attributed to one of software technology's most desirable properties. Specifically, software technology assists in weapon system evolutions by permitting gains in weapon system performance and provides system application flexibility without costly hardware configuration changes. Because of software's perceived inherent adaptability, military commanders are often impatient to introduce software changes that will permit weapon systems to address new threats, apply new tactics, or accommodate changing environments. Therefore, "user" software technology concerns usually do not focus on software development problems, but instead focus on operational weapon system evolution and support problems that adversely impact their ability to (1) rely on and trust the system, (2)

effectively use the systems in conjunction and in context with other systems, and (3) rapidly modify the systems to meet changing needs.

The user must have confidence that a software-intensive system will work the intended way, will have a known sustained level of performance over time, and will be effective when used by assigned personnel. This high level of confidence in the system must be sustained at a high level during support and maintenance of the weapon system, and especially as new software enhancements are introduced.

Today's weapon systems must function effectively in context with other systems and in rapidly changing environments. The software systems must be able to quickly incorporate the changes, integrate new data, compute results and display the revised situation in the proper context for a user to make the correct tactical decision and/or interoperate with other systems.

Rapid technology advances influence the designs of DoD weapons systems. Unfortunately, similar technology finds its way into systems of potential adversaries. Therefore, the field commanders and weapon system operators must have software systems that are flexible enough to evolve with changing technology and operational needs. These operational software systems must also possess characteristics that make them easy to diagnose and isolate faults, prescribe corrective actions and institute system fixes.

An outline of common software problems clustered in terms of perceived user operational problems was developed by the workshop participants and is presented in Table B-2 of Appendix B.

3.2 System Acquisition Process

This section of the report attempts to isolate the "classic problems" that influence software deployment and are associated with the weapon system acquisition process. These software problems are virtually ubiquitous across software intensive systems and are most frequently associated with weapon system cost, schedule and performance constraints.

Software intensive systems are often initiated with an inadequate and unrealistic understanding of the basic system requirements, software requirements, software development costs, and associated schedules. System requirements tend to grow as users and developers gain a better understanding of the realistic properties and capabilities of the system under development. New and evolving system requirements translate to additions or changes in software requirements, thus, further exacerbating the growing cost and schedule problems. These schedule problems are, in part, due to the fact that the software development is initially paced by the hardware and architectural development. The resulting cost growth is generally due to the extended schedules. The perception of software cost growth problems is further exacerbated when system designers underestimate workloads due to a lack of credible software development metrics.

Development teams often lack (and because of the source selection process, often are not chosen for their) experience and expertise in advanced software and computer technology applications areas. Frequently, DoD focuses on hardware contractors as opposed to system integration contractors. These problems are usually exacerbated by the contractor selecting and freezing the hardware configurations before specifying the software (a problem compounded by inadequate interface definition and coordination between the various hardware and software design teams which are often separated). Finally, many system design activities fail to implement and enforce sound software development standards as well as proven design methodologies. The workshop participants felt that this last problem is influenced in part, by the lack of DoD incentives that would stimulate software productivity, such as the very controversial issue of

software "Rights-in-Data".

The September 1987 Defense Science Board Task Force on Military Software presented a number of recommendations addressing a wide range of software-related acquisition problems (including this data rights issue). A follow-on Workshop on Military Software was specifically requested by the Defense Science Board Chairman and chaired by Mr. Charles Zraket during the summer of 1988. This Workshop report strongly endorsed the recommendations of the Task Force report and recommended that DoD use it as a basis for the long-term management of military software research and acquisition. However, to date, the vast majority of these software-related acquisition recommendations have not been implemented by DoD.

3.3 Generic Software Technology Areas

There was a general perception by the workshop participants that many of the identified software-related deployment problems would be mitigated if additional research and development efforts were focused on generic software technology areas that transcend specific program requirements. If common system software technology requirements could be identified early enough, potential economies of scale may be realized by clustering research efforts.

Research areas would need to be at a high enough level of abstraction to cover a significant number of Service requirements, yet have applicability and transferability to specific program efforts. Unfortunately, the workshop participants knew of neither an existing convenient forum (either at the Services or DoD levels) for identifying the generic software technology needs nor a convenient vehicle for reviewing and sharing specific software technology advances across Services and system program offices.

The workshop participants, recognizing this dilemma, attempted to identify generic software technology areas that have wide applicability to specific system and Service requirements as well as address the issues and problems identified by the workshop (and summarized) in Tables B-1 & B-2. An unprioritized listing of the potential generic system software technology areas identified by the workshop is presented in Table B-3 in Appendix B.

4. FINDINGS AND RECOMMENDATIONS

The principal findings of the workshop, as they relate to the DoD's ability to deploy and support software intensive weapons systems are listed in the following sections. For each of the findings, specific recommendations are provided for consideration by DDDRE(R&AT) as potential actions to improve the deployment of software technology in weapon systems.

4.1 Deployed Military Software Improvement Programs

4.1.1 Findings

By viewing the growing software problem from the "user's/commander's" perspective, the workshop participants discovered an important missing ingredient in the focus of DoD's software technology base programs. An overall mechanism to support, encourage, and expedite needed military software improvements during weapon system deployment is lacking. As a result, the attainment of measurable and predictable improvements in military software is seriously inhibiting weapon systems adaptability and evolvability, and adversely impacting testability of software intensive systems.

The costs of using, maintaining, and supporting currently deployed software intensive weapon systems are excessive. Cost avoidance opportunities need to be identified and exploited, especially in cases where advanced software and hardware retrofits will increase reliability and maintainability while reducing operating and support costs. Workshop participants were convinced that small investments in software and computer technology research targeted at deployed systems would have significant pay-offs. Furthermore, the vast majority of software technology advances that would improve DoD's operational systems software deployment will also yield a commensurate improvement in software quality and productivity for new systems. The workshop participants felt that focusing software technology research and development on problems related to deployed systems would not only ensure the early realization of both enhanced system software performance and support cost avoidance opportunities, but the software technology advances would be more acceptable to the risk conscious program managers since there would now exist demonstrated benefits.

4.1.2 Recommendation

The DDDRE(R&AT) should establish a comprehensive approach for improving military software during deployment. Focus should be on the phases of the "Software Life Cycle" that have the most influence over the deployment of software intensive weapons systems, that inhibit systems software adaptability/evolvability, and that provide the most leverage in attaining improved operational performance (or capability per unit cost). DoD resources should be applied to those software problems or software features which are military or intelligence-specific and hence cannot depend on consumer market place forces to drive commercial sector spending in research and engineering. The following outlines the recommended approach.

a. Dispatch a small team of experts to discuss the software problems and the approaches proposed in this document with military operational commands to:

   1. Validate the findings and approach of this report,

   2. Solicit additional concerns, problems, and potential high pay-off software projects based on their "hands-on" experiences, and

   3. Obtain willing "user" commitments to include relevant proposed actions in the Command's program.

b. Refine the approach and recommendations of this report based on the results of the team visits (Section 4.1.2 a).

c. Identify a few high priority representative software-intensive military or intelligence systems needing improvement. High priority project opportunities should include weapon systems that fall in the procurement (6.4, 6.5, 6.7, etc.) as well as Program 2 and 3 categories. Software problems or features should be drawn initially from the development testing, operational testing, and maintenance phases of the software life cycle. The underlying objective is to accelerate advanced software applications in the life cycle phases of weapon systems where the majority of software development, upgrades, modernization, test, and evaluation are now funded and performed. Recommended approaches include:

   1. In conjunction with the visits discussed in Section 4.1.2a, the small team of experts should ask the users to identify critical software problems and related high pay-off software projects. For these identified projects, DDDRE(R&AT) should solicit the support of operational commands/commanders in the form of statements of requirements (SORs) and their continuing support as informed guaranteed customers.

   2. DDDRE(R&AT) should task the Services to identify software intensive systems currently experiencing operational software-related problems. Based on these responses, DDDRE(R&AT) should investigate opportunities to use the Defense Acquisition Board (DAB) Milestone IV and Milestone V Reviews as a forum for identifying potential software technology test-bed demonstration projects.

d. Establish several high pay-off software technology test-bed demonstration projects to be conducted by each of the Services. The objective of these projects should be to develop processes, procedures, and metrics to counter current software deployment problems.

   The demonstration projects should focus on upgrades to existing operational software intensive weapon systems currently experiencing critical software difficulties. The goals of the software technology test-bed demonstration projects would be (1) to establish a baseline metric to measure software technology enhancement results, (2) to develop an improved maintenance and support environment for the existing system, (3) to demonstrate significant (order of magnitude) improvements in ability to maintain and evolve the existing system, (4) to begin to apply available software engineering technology to the software re-engineering tasks (as opposite to "bug removal"), and (5) to abstract the results from the experimental projects to develop an approach for other software intensive systems.

4.2 Software Technology Funding Support (Ongoing Programs)

4.2.1 Findings

The rate of software technology evolution, although advancing moderately, has not kept pace with DoD weapons systems requirements for more software with increasing complexity, and the current cost of software maintenance and support is increasing rapidly. The workshop participants were unanimous in their conclusion that the current budget for software technology is not commensurate with DoD's development, deployment, maintenance and support needs for software intensive weapons systems. They felt that significant increases in software technology base efforts are required even though DoD is entering an austere funding period.

4.2.2 Recommendation

DDDRE(R&AT) should, as a minimum, continue to fully support the existing ongoing software technology base programs including Ada, STARS, the SEI, along with the ongoing software technology development efforts at DARPA and the Service Laboratories in the face of an austere budget. Given that the combined DoD FY 1989 Software Technology Base funding allocation will be less than 0.3 percent of the projected $29 billion DoD software acquisition and maintenance requirements for 1990 (see Section 2.4), DDDRE(R&AT) should task the Services

and DARPA to specifically reassess their software technology base requirements for FY 1991. DDDRE(R&AT) should take the lead in ensuring that the software technology base funding priority is increasing commensurate with the rising trend of software-related deployment and support costs.

4.3 Generic Software Technology High Priority Efforts

4.3.1 Findings

Several aspects of each of the generic software technology areas highlighted in Table B-3 are at the leading edge of technology development and are uniquely applicable to DoD weapon systems. Given the growing significance as well as the increasing maintenance/support cost burden of software technologies, the workshop concluded that DoD needs to investigate opportunities to expand the focus of DARPA and the Service Laboratory research efforts into all of these generic software technology areas. The workshop participants observed that neither the Services nor DoD had in place a convenient forum for identifying generic software technology needs. DoD lacks a convenient vehicle for reviewing, sharing and stimulating advanced software technology applications across Services and system program offices.

4.3.2 Recommendation

DDDRE(R&AT) should task the Services and Agencies to establish (one or more) "lead agents" for selected critical software technology areas. The lead agents should be carefully selected for their technical expertise in advanced software and mission critical computer technology disciplines. The lead agents will supplement R&AT expertise and help maintain a level of technical currency on critical software-related issues by providing an annual summary of the Services' software-related programs, issues, needs and problems. The primary function of the lead agents will be to help identify Service software technology related problems and requirements while promoting the sharing of software technical information and stimulating advanced software technology applications across Services and Program offices.

Software technology areas that are currently too high a risk for specific ongoing programs, yet have the potential of meeting critical DoD system requirements of the future, should be given high DoD priority and be monitored by the Service lead agents. The lead agents should be delegated the specific responsibility of assessing and identifying critical software technology areas that have targeted application potential within 5 to 10 years. Such technology targets should be supported in the context of other projected Service and DoD requirements. The lead agents should be tasked with coordinating critical resources, defending the software technology base budget requirements, promoting software technology transition opportunities, and providing a status briefing to DDDRE(R&AT) on an annual basis. As a start, the lead agents should begin by focusing on the list of generic software technology areas identified in Table B-3.

4.4 Recommendations of Previous Studies

4.4.1 Findings

One of the most discouraging findings of the workshop was the lack of significant and consistent action on the recommendations of numerous "Software Reports" commissioned by DoD policy officials in the recent past.

The software-related problems associated with developing, deploying and supporting software intensive DoD systems are well documented. There are numerous software studies sponsored by the Services, DoD and the GAO. Nearly every one of these studies implies that the consequences associated with the DoD software-related technical and management problems are growing. One of the more recent studies commissioned by DoD was the *Defense Science Board Task Force on Military Software*. The workshop participants were unanimous in

their opinion that this effort provided a comprehensive review of DoD's software-related problems, and that the findings and recommendations were still current and valid. This observation is in total compliance with the results of the follow-on "Workshop on Military Software" conducted at the request of the chairman of the Defense Science Board. The cover letter transmitting the results of this workshop stated that they "strongly endorse the recommendations of this report and recommend that DoD use it as a basis for the long-term management of military software research and acquisition."

4.4.2 Recommendations

DDDRE(R&AT) should use the Science & Technology Committee of the Defense Acquisition Board to review, sponsor, and promote full implementation of the recommendations that resulted from the September 1987 Defense Science Board Task Force on Military Software.

4.5 DoD Software Responsibility and Authority

4.5.1 Findings

One of the critical problems which has been identified in almost every study of DoD software problems has been the lack of any single, responsible official or spokesman for military software. The November 1982 Defense Science Board Task Force on Embedded Computer Resource (ECR) Acquisition and Management concluded that there was no consistent management approach across the OSD Staff and the Military Departments relating to software and computer technology. From 1976 up to the time of this Defense Science Board report, OSD had been relying on the DoD Management Steering Committee for Embedded Computer Resources (MSC-ECR) to address the common computer and software problems. This Task Force report stated that:

> OSD has attempted to manage this ever-growing portion of its business through an ad hoc committee approach. The magnitude of the complex and interrelated issues to be resolved in this area have clearly outgrown this approach. We feel it is time to recognize the need for a meaningful approach which places responsibility in a line function. [DSB, 1982, 54]

As a direct result of this Task Force, the MSC-ECR was discontinued and action was taken to centralize software and computer acquisition management within the Office of the Under Secretary of Defense for Research and Engineering. Subsequent to this time frame, however, DoD has undergone several organizational changes that have basically reversed this centralization trend. At present, DoD software and computer advanced technology development, acquisition management, test & evaluation, policy, and the software intensive systems maintenance and support responsibilities are fragmented over a range of OSD offices. Quite unintentionally, DoD has been conveying an erroneous message that the relative priority reserved for software and computer technology has decreased since the 1982 Defense Science Board. The workshop participants felt that this perception is further perpetuated by both the fragmentation of responsibilities and the implementation of ambiguous software acquisition policies.

Furthermore, the workshop participants observed that most DoD contracts are void of contractual incentives which might stimulate the software systems engineer to design in long-term supportability and maintainability features. Software maintainability, robustness, flexibility, modularity, and testability are very seldom specified as system or procurement requirements. At present, operational support problems for mission critical computer software embedded in DoD weapon systems are growing, while at the same time DoD management and policy formulation are fragmented. The following is only a partial list of specific software-related areas needing urgent direct DoD management oversight and evolving implementation policy:

standards, rights-in-data, common languages, common interfaces, metrics, prototyping, reuse, and contractual incentives. These are all problems that transcend Service/Agency requirements and need to be addressed in a forum that will allow these issues and problems to be identified and resolved.

4.5.2 Recommendations

DDDRE(R&AT) should become an advocate for and begin an initiative to consolidate DoD software and computer policy, management, and oversight within a structured forum that is commensurate with software technology's growing importance. This forum should provide direct centralized focus on the growing number of software-related common DoD policy, programmatic and budget issues that transcend specific Service programs.

Within the Office of the Under Secretary of Defense (Acquisition), (OUSD(A)), resides all of the functional areas (with both responsibility and authority) necessary to address the current mission critical and embedded computer software-related problems. The following are several recommendations developed during the workshop that take this fact into account and specifically address this very complex software-related responsibility and authority problem:

a. The workshop participants recommended that DDDRE(R&AT) become an advocate for and begin an initiative to establish a Director for Military Software Improvement within the OUSD(A). This can be done by creating a new position or assigning an existing staff member this responsibility and associated authority. If it resides within an existing Staff Office, the principal must be given direct line access to OUSD(A) to resolve software-related conflicts. The Director of Military Software Improvement should be established with a "sundown clause" stating that the position (or assignment) will remain in effect for a period not to exceed three years. The presence of a sundown clause will permit unique working relationships across OUSD(A) Staff functional lines. The sundown clause, will in effect, establish a finite schedule as well as a compelling goal to formulate a workable solution that equitably addresses the many concerns across DoD functional lines.

   During this period, the Director of Military Software Improvement should be designated as the Officer of Primary Responsibility (OPR) for identifying, managing, integrating and implementing software development, acquisition and deployment policy. The Director of Military Software Improvement should also be designated as the principal advisor to the Defense Acquisition Board (DAB) on all matters involving computer and software technologies.

b. DDDRE(R&AT) should advocate and begin an initiative to establish a DoD Management Steering Committee for Military Software Deployment Improvement (MSC-MSDI) similar to the previous MSC-ECR. It should operate under the co-chairmanship of the Director of Defense Research & Engineering (DDRE) and the Assistant Secretary of Defense (Production and Logistics) (ASD(P&L)) with representation from the Service Assistant Secretaries and USD(A) or his designate. Placing it under this co-chairmanship should eliminate the earlier concern that the MSC-ECR failed to focus management attention at a high enough level. It will provide a direct forum for addressing policy and program issues that transcend Service/Agency requirements. The MSC-MSDI, in conjunction with the recommended DDDRE (R&AT) led initiative to accelerate software deployment (Section 4.1.2), should be recognized as the principal mechanism for planning, programming and budgeting of resources that may fall outside the Tech Base. The MSC-MSDI should work in close conjunction with those Service Program Managers/Program Directors investing heavily in high priority software intensive system procurements.

c. Until such time that the organizational-related software responsibility and authority problems are resolved, DDDRE(R&AT) should take the lead in developing and

distributing a software responsibility and authority guide. The intent of the guide should be to permit a greater understanding of the current software policy, review, coordination and oversight responsibility within DoD.

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APPENDIX A

Software Technology Development and Deployment Plan
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APPENDIX B

Tables of Software Issues, Common Problems and
Generic Areas With Application Potential

1. CATEGORIZATIONS OF SOFTWARE ISSUES

DoD is continually asking what are the software problems and how may they be resolved. The SEI observed that "There is no single problem," but a series of problems that tend to be repeated over and over again. The following table summarizes software issues addressed in recent reports [DSB 87; Zraket 88; Nash 88; Druffel 88; OIG 88].

Table B-1. Categorization of Software Issues

- Production Environment
  - — Lack of methods
  - — Lack of support tools
  - — Failure to reuse software
  - — Insufficient capital investment
- Life Cycle
  - — Ineffective management of life cycle activities
  - — Difficulty measuring and estimating cost, quality, and productivity
  - — Poor requirements definition and analysis
  - — Continuing software acquisition problems
  - — Limited technology transition
- Technical and Management Professionals
  - — Lack of qualified personnel
  - — Inadequate training and education opportunities/services
- Software Product
  - — Failure to meet needs
  - — Failure to operate correctly

2. COMMON SOFTWARE PROBLEMS CLUSTERED IN TERMS OF PERCEIVED USER OPERATIONAL PROBLEMS

The workshop participants attempted to address the various types of common software problems related to deployment of operational systems. The following table is an outline developed by the workshop participants to summarize common software problems in terms of perceived user operational weapon system problems.

Table B-2. Common Software Problems Clustered in Terms of Perceived User Operational Problems

- Assurance that the System Meets the Operational Needs
  - — Ability to test the software
  - — Ability to explain/define system software requirements
  - — Ability to quickly satisfy new and evolving requirements
    - o Characteristics of correctness, availability, performance and security
    - o Ease of use
  - — Ability to "fail-safe" or "fail-soft"
- Assurance that the System Works in Context with Other Systems
  - — Ability to interoperate
  - — Ability to rapidly set-up and link to other sites
- Assurance that the System can Meet Changing Needs
  - — Ability to keep systems operational
    - o Rapidly diagnose problems
    - o Understand effects of changes
  - — Ability to change functions
    - o Responsive to evolving requirements
    - o Timeliness of change
  - — Accessibility of software resources
    - o Qualified people
    - o Maintenance and support

3. GENERIC SOFTWARE TECHNOLOGY AREAS WITH WIDE APPLICATION POTENTIAL

The workshop participants attempted to identify generic software technology areas that have wide applicability to system and Service requirements yet might not be justified (in terms of return on investment) for a single specific program. Also included in the summary of generic software technology areas are research and development efforts that have the potential of addressing the issues and problems identified by the workshop participants in Tables B-1 and B-2. The following is an unprioritized listing of potential generic system software technology areas that should receive increased emphasis and consideration by DoD.

Table B-3. Generic System Software Technology Areas

- Software Testing Technologies
- Configuration Management/Version Control Management Tools
- Software Modularity and Reuse Standards
- Software Prototyping Concepts & Tools
- Software Metrics
- Compiler Instrumentation and Optimizations
- Software Reverse Engineering Tools
- Object Oriented Programming Tools

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